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ABSTRACT

This publication presents general guidelines for exercise prescription that have an anatomical basis but also consider the exerciser's ability to do the exercise correctly. It reviews various common questionable exercises, explaining how some exercises, especially those designed for flexibility and muscle fitness, can cause harm. Safer alternatives are provided. Section 1 discusses parameters of evaluation. Section 2 describes the spine. Section 3 explains spinal movements, focusing on the neck (cervical) area, the trunk area, and the pelvic area. It examines exercise concerns related to cervical spine range of motion; hip-joint flexion range of motion; hip-joint/trunk (extension strength); trunk/hip-joint (flexion strength); and other nuances of abdominal strength. Section 4 discusses the knee, noting exercise concerns and describing the standing quadricep/hip-flexor stretch, the hurdler stretch, knee hyperflexion, and high impact exercises. Section 5 summarizes the issue, re-emphasizing the fact that certain exercises that are appropriate for some people may be totally inappropriate for others. The quality of the exerciser's movements is a critical variable when evaluating exercises for inclusion in a conditioning program. Criteria to consider when judging an exercise or an exerciser are included. Several important definitions are also provided. (Contains 41 references.) (SM)

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Questionable Exercises

A Note from the Editors

The focus of virtually all previous issues of the **PCPFS Digest** has been on the health-related benefits of physical activity and other healthy lifestyles. Too often we forget that while physical activity has many benefits, when done improperly it can have negative consequences. For this issue of the **PCPFS Digest** we asked Wendell Liemohn and his colleagues to describe some of the more common questionable exercises. The intent is to describe how some exercises, especially those designed to produce flexibility and muscle fitness, can cause harm and to provide alternatives that are safer.

Introduction

Any activity selected for an exercise program should have some underlying value (e.g., improve flexibility, strength, cardiovascular fitness). However, even some exercises that have underlying value might have elements that can make them inappropriate or even contraindicated if done incorrectly. Thus, an exercise for extremely physically fit individuals can be appropriate because the quality of movement they display in doing it meets the objectives for which the exercise was designed. However, if the same exercise were done by individuals with poor physical fitness (e.g., lack flexibility, have weak abdominal muscles); their renditions of the exercise could be deemed totally inappropriate (or even contraindicated) because their *quality* of movement is poor. The purpose of this issue is to present general guidelines for exercise prescription that have an anatomical basis but that also consider the exerciser's ability to do the exercise correctly (i.e., show good quality of movement). To aid the reader several important definitions are included in highlighted boxes. The terms defined are printed in bold in the text of the paper.

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Parameters of Evaluation

Before discussing any exercise, anatomical and biomechanical factors should be considered. For example, knowing how much "safe movement" can occur at a joint is of obvious relevance. After presenting the anatomical/biomechanical characteristics of the area of the body pertinent to the exercises to be addressed, we will examine a few of the more "notorious" exercises and discuss how **movement quality** and **movement tempo** relate to their appraisal.

The Spine

The spinal column consists of 7-cervical, 12-thoracic, 5-lumbar, and 5-fused-sacral vertebrae (i.e., the sacrum); the latter

Movement Quality. Typically individuals who are physically fit and have good body awareness, can do an exercise precisely as it should be done; thus, their quality of movement is usually good. However, individuals lacking in these variables may attempt the same exercise and produce such incorrect movements that for them the exercise is inappropriate. ***Movement Tempo.*** If some exercise activities are done too quickly and without good body control, the momentum of the body part being moved may be so great that the movement exceeds the physiologic limits of a joint. This would be an example of a ballistic movement; a movement initiated by forceful muscle contraction followed by an inertial or coasting movement of the body part.

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transfers the weight of all structures above it to the other bones of the pelvis. Any two vertebrae and their intervening disc are called a motion segment of the spinal column. A motion segment is the smallest functional unit of the spine; the joints that comprise it include the (a) anterior joints between the vertebral bodies and the disc that separates them and (b) posterior joints between the paired facets (i.e., junction of the superior and inferior articular processes). Intervertebral discs act as spacers and shock absorbers for the spinal column; discs also permit movement between vertebrae. The peripheral fibers of each disc (*annulus fibrosis*) and its top and bottom (*vertebral end-plates*) enclose the disc's fluid center (*nucleus pulposus*).

If you are having difficulty perceiving the structure of an intervertebral disc, just think of it as a thin jelly donut. The donut part would represent the ***annulus fibrosis*** and ***vertebral end plates***; the jelly would represent the ***nucleus pulposus***. Some neck and low back problems relate to movement of the nuclear "jelly" material from its normal confines and into contact with pain receptors in the annulus fibrosis or adjacent tissues.

Spinal Movements:

Neck (Cervical) Area. Because the cervical spine has an exceptional amount of movement and is hard to depict pictorially, we will describe cervical movement in terms of the degrees of range of motion (ROM) from one end-point to another (e.g., end-ROM in flexion to end-ROM in extension). Using these descriptors, the cervical vertebrae have about (a) 145 degrees of flexion and extension, (b) 90 degrees of lateral flexion (e.g., 45 degrees to each side), and (c) 180 degrees of axial rotation[1]. The greatest amount of rotation occurs between the top two cervical vertebrae (C1 & C2); approximately 9-11 degrees of motion exist between the remaining motion segments of the cervical vertebrae.

Trunk Area. Figure 1 is an illustration of trunk ROM showing ROM extremes from lumbosacral hyperextension to lumbosacral flexion. Note that lumbar flexion is, in essence, just a removal of the lordotic curve; people really do not flex their lumbar spines. If, for example, movement exceeds an individual's end-ROM for spine flexion (or lateral flexion), there could be (a) compression damage to discs, neural components, and vascular structures on the side of the bending and (b) stretching of ligamentous and other soft tissues on the opposite side. If end-ROM in rotation is exceeded, the outer fibers of discs could be torn. Although seemingly innocuous, movements such as those listed may lead to **repetitive microtrauma**. The first few times normal ROM of a joint is exceeded, perhaps only a few bands of collagen (a constituent of connective tissue seen in ligaments, discs, and in other soft-tissue structures) is damaged. However, repetitive microtrauma can eventually lead to serious damage of tissues.

Repetitive Microtrauma (also called repetitive motion injury). If one bends a paper clip a couple of times, it is still strong but its molecular makeup has been changed forever. With continued bending it will eventually break. This is similar to what happens in a ***repetitive microtrauma*** injury to soft tissue structures such as ligaments and intervertebral discs. The minor damage is not noted initially; however, by the time it reaches pain threshold it has become serious.

Fig. 1. This figure presents the limits of lumbar spine ROM in the sagittal plane (i.e., extremes from backward to forward bending). If the individual were to reach towards his/her toes from the forward position, the additional movement would occur at the hip joint. (Adapted from White and Panjabbi[1])

Some exercise leaders suggest that any spine hyperextension should be avoided. However, hyperextension is a natural movement and it is in the best interest of the biomechanics of one's spine to maintain this mobility. If such mobility is not maintained it will be lost[2,3]. Nevertheless, it is acknowledged that uncontrolled or ballistic-hyperextension movements of the spine are totally inappropriate because they can stress and damage the posterior aspects of one or more motion segments. But, "slow and controlled" hyperextension movements are appropriate for inclusion in exercise programs; in fact they are a prime element in the very popular McKenzie exercise therapy program for individuals with neck or low back pain[4-6]. Nonetheless, it is important that spine movements are carefully taught and monitored by exercise leaders, for some individuals do not have a very good awareness (kinesthetic sense) of how they move and position their body parts when they exercise.

Excessive and uncontrolled rotation movements of the spine (e.g., as in a "no" headshake) are of utmost concern. As previously indicated, the greatest rotation exists between the first and second cervical vertebrae; however,

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there are about 9-11 degrees of rotation between the other motion segments of the cervical vertebrae. In the lumbar region only 1-3 degrees of motion exist between each vertebra; here the restriction is due to the structure of the posterior portions of the motion segments (i.e., the facet joint). If spinal rotation exceeds a joint's physiological limits, the excessive stress may be placed on intervertebral discs, their supporting ligaments, and their neural and vascular tissue.

Ballistic Rotation. Ballistic rotation movements of the spine that are quick and with little control have been cited as being a major cause of neck as well as low back problems because of the stress that they place on discs and other structures of the spine. This movement is truly contraindicated.

Pelvic Area. The muscles crossing the hip joint can be viewed as "guy wires" that control pelvic positioning; if any of these guy wires are too tight, the affected individual will have difficulty controlling pelvic position with the trunk musculature. The posterior-lateral wall of the pelvis includes the five fused sacral vertebrae (i.e., sacrum and ilia). Because these joints (i.e., the sacroiliac) permit so little movement, the pelvis in essence becomes the foundation of the spinal column. Therefore, tightness in any muscle crossing the hip joint can affect the biomechanics of the spine. It is for this reason that ROM at the hip joint is often measured and its improvement is often an objective of exercise programs. The normal ROM for the hip joint in forward and backward bending is 135 degrees; this includes 10 degrees of hip extension and 125 degrees of hip flexion[7]. Besides the joint capsule, hip joint extension can be limited by tightness of the hip flexor muscles (e.g., iliopsoas muscle). When the knee-joint is extended, hip-joint flexion can be limited by the hamstring muscle group that crosses both hip and knee joints. Although other hip-joint muscles are also important, the flexors and extensors of the hip joint have greater roles in exercise considerations than do the other muscles, and thus they are the only ones that we will discuss for this area.

Exercise Concerns:

Cervical Spine ROM. The *yoga plough* is done by extending the legs overhead and backwards behind the head and neck; this movement involves transferring the weight of the body over the cervical spine (see Fig. 2). The purpose of this exercise is to stretch the lower back; however, the extreme amount of flexion of the neck that occurs in doing the exercise can be problematic. This exercise would be particularly inappropriate for individuals with either arthritis or osteoporosis of the spine, or amenorrheic women[8, 9]. However, this exercise may not pose a problem for healthy youngsters[8].

Fig. 2. The Yoga Plough Exercise. Although this exercise can stretch the low back (e.g., if the legs were bent and brought to the mat), it can place an undue amount of the body weight on the cervical and thoracic spine. It is for this reason that it would be inappropriate for individuals with either arthritis or osteoporosis of the spine, or for amenorrheic young women.

On the other hand, exercises involving neck hyperextension (e.g., as seen in *neck circles*) are considered potentially dangerous if done forcefully and quickly. This type of exercise is inappropriate because it may result in the compression of neural and vascular structures at the base of the skull[8, 10], and potentially damage discs and other soft tissue structures. Obviously *neck hyperextension* can be dangerous for individuals with degenerative joint disease, osteoporosis, or who have suffered whiplash injuries. However, hyperextension movements can be considered safe if done slowly and with controlled movement in the normal range of motion[4, 8]. Conversely, much less support exists for *bridging* as done by wrestlers and football players to strengthen the neck; bridging is inappropriate for most everyone because of the extreme pressure it places on cervical discs[8].

Hip-Joint Flexion ROM. The movements inherent in both the *fingertips-to-floor* (FTF) and the *sit-and-reach* (SR) exercises and tests have been questioned with respect to endangerment of the spine[11-13]. If either activity is done repeatedly, and if the exerciser has tight hamstrings, the limited excursion at the hip joint can transfer the stress to the connective-tissue structures of the spine[12, 14]. However, if the exerciser has good hip-joint flexibility, the activity is more apt to achieve what it is intended to do, namely stretch the hamstrings. If the *tempo* of the activity were increased markedly by one with tight hamstrings, the torso would have greater momentum (i.e., more ballistic in nature), and there would be a greater chance that the posterior ligaments of the vertebral column could be sprained[11].

An important point to remember in administering either the finger-tip-to-floor or the sit and reach is that the quality of the movement may be more important than the number of centimeters reached. A major quality point to

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Fig. 3. Sit-and-Reach (SR). In the individual depicted the angle of the sacrum is about 50 degrees with the floor; this angle should be a minimum of 80 degrees[7]. If this individual with very tight hamstrings were to use this as a stretching activity, most of the stress would be absorbed by the soft tissue structures of the lumbar spine; thus the exercise would be most inappropriate.

check is the angle of the sacrum; in the sit and reach it should be 80 or more degrees with the floor; a book or small object with a 90-degree angle placed next to the sacrum provides a good criterion[7]. If this angle were less than 80 degrees (see Fig. 3) and the individual practiced this activity (or the comparable finger-tip-to-floor), the stress in stretching would be more apt to occur in the connective tissue structures of the spine rather than in the hamstrings[12, 15]. Ideally the spine should make a smooth arc; there should neither be a flattening or an excessive curve in any area.

Sit and Reach Modifications. Cailliet[12] contends that his protective hamstring stretch with only one leg extended instead of two places less stress on the lumbosacral area. Although we did not find a significant stress reduction when we studied this issue[16], we recommend his stretch. Also, the one-leg extended version of the sit and reach permits checking for symmetry, an important fitness element. It should be mentioned that if the finger-tips-to-floor test, or any of the sit-and-reach tests described, is used, hamstring length is the factor being measured, not low back flexibility[17-21]. Tests have also been developed that partial out the effect of (a) disproportionate arm/leg length ratios[22] and (b) tightness of the soft tissue structures behind the knee[23].

Hip-Joint/Trunk (Extension Strength). In the previous discussion on spine extension ROM, we mentioned that the movement is often done without active contraction of the muscles of the spine; therefore hyperextension movements are appropriate as long as they are done slowly and under total control (i.e., not done ballistically). On the other hand, if strengthening the lumbar spine musculature is the objective, the rules change. If there is active contraction of these muscles (e.g., spine muscles in a Roman-Chair-type activity), a good rule of thumb to follow is to limit extension to the extent of one's normal standing lumbar lordosis (i.e., do not hyperextend)[24].

Trunk/Hip-Joint (Flexion Strength). In Figure 3 the reader is reminded that (a) the amount of lumbosacral flexion is in essence limited to the removal of the lordotic curve and (b) any subsequent flexion occurs at the hip-. Because the abdominal muscles do not cross the hip joint, they obviously cannot produce flexion at this joint. However, individuals with weak abdominal muscles often do *full-sit-up-type exercises* entirely with their hip flexors[7]; the role of the hip flexors in this type of sit-up becomes even more dominant if the feet are held[25]. The full sit-up (either with legs bent or straight) has been criticized for a number of years[7, 13, 26, 27]; moreover, Saal and Saal[28] believe that this exercise can cause low-back injury. This possibility is supported by two recent studies that have shown that either the straight-leg or bent-leg sit-up can place extremely high compressive forces on intervertebral discs[29, 30]. Although the timed *full-sit-up* is now only used in a few settings[31], the *tempo* of the movement can add to its drawbacks. For example, too much flexion may occur at the neck if the hands are placed behind the head. If done too quickly, movement quality diminishes; however, if an individual with strong abdominal muscles does this exercise at a cadence of 20 repetitions per minute, movement *quality* is apt to be good. Nevertheless, even this cadence would probably be questionable for those deficient in abdominal muscle strength.

Other Nuances of Abdominal Strength. A safe "crunch-type" test was recently developed at Georgia Tech University[32]; the only critical review of this test raised minor statistical points[33]. Of more importance, although the test appears safe, its biggest drawback is that it only permits evaluation of the strength of the rectus abdominis. If functional spinal integrity is of concern, the strength of the obliques and the transversus abdominis (i.e., lateral abdominal muscles) should be evaluated[24, 34].

The Knee

Besides being the largest joint in the body, the knee joint is very complex because it includes articulations between the (a) tibia and femur (tibiofemoral joint) and (b) patella and femur (patellofemoral joint). The knee is particularly susceptible to injury because of the high forces it sustains due to its location between the body's two longest lever arms (femur and tibia)[35]. Poor technique or uncontrolled movement during exercises increases the risk of injury to the knee.

Exercise Concerns:

The medial structures of the knee (i.e., medial collateral ligament & medial meniscus) are put at risk for injury when individuals perform flexibility exercises (such as the

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Fig. 4. Standing Quadricep/Hip-Flexor Stretch. In doing this stretch the leg should be pulled straight back rather than back and to the side as shown. As depicted, excessive stress is placed on the medial soft-tissue structures of the bent leg; a simple way to avoid this stress is to hold the ankle with the opposite hand. (Note that the exerciser is leaning forward at the hip joint; although this is a common mistake and the posture is safe, increases in hip-joint flexion decrease the chance that the hip flexors are being stretched.)

standing quadricep/hip-flexor stretch) in which the hip is abducted during the stretch[36] (Fig. 4). One way to avoid this possibility is to use the contralateral hand to hold the ankle.

The *hurdler stretch* is unique because it can be used for either stretching the hamstrings or quadriceps, dependent upon whether body lean is forward or backward (See Fig. 5). When used for stretching the hamstrings, the individual leans forward. In this position a considerable stress is placed on the medial structures of the bent leg; strain or discomfort in the hip and groin area may also occur because the femur of the bent leg is placed in extreme rotation. A safer alternative is to bend the knee in front of the body rather than to the side. This is the stretch originally recommended by Cailliet[12] and subsequently adapted for use in a testing protocol by The Cooper Institute for Aerobics Research[37].

Fig. 5. Hurdler Stretch. This exercise is inappropriate for stretching either the (a) quadriceps (leaning backward) or (b) hamstrings (leaning forward). If this individual were to place his/her right foot adjacent to his/her left knee, it would be a beneficial hamstring stretch[12].

If the individual in Figure 5 were to lean backward, the quadriceps would be stretched; however this movement too has its drawbacks because the position of the bent leg does not allow the pelvis to rotate as the trunk is brought backward. This results in a hyperextension stress being placed on the lumbar spine. Furthermore, the rotation of the tibia relative to the femur may damage the soft tissue structures of the knee.

Also questionable are exercises that involve knee *hyperflexion* (e.g., 120 degrees or more) because they increase forces markedly at the patellofemoral joint. In weight-supporting activities, for example, these forces have been documented to be 2-3 times a person's body weight when the knee is flexed at 90 degrees[35]. Exercises that involve deeper squatting (i.e., more hyperflexion) or that are performed with added weight would increase the patellofemoral forces even further. The supportive structures of the knee are placed in a vulnerable position in these activities; therefore, they should be avoided by individuals who have a history of knee injury[38].

Sports such as weight or power lifting, ballet, and gymnastics sometimes require movements that place the knee in a hyperflexed position of more than 90 degrees. Although elite athletes in these sports may be capable of performing knee hyperflexion exercises without any problem, other types of individuals may benefit less from them because of the risks of injury[8, 39].

In general, *high impact* exercises are common injury mechanisms for the hip, knee, ankle and foot. Particularly questionable are jumping or bouncing type movements in which the exerciser lands on one foot; research has shown that vertical ground reaction forces for such movements can be 5-6 times the vertical force experienced in walking[40]. *High impact* aerobic dance movements that require bouncing in the same spot can increase the risk of shin pain, compartment syndrome, and stress fractures of the tibia and fibula[41]. However, a resilient exercise surface would lessen the chances of injuries.

Summary

It should be noted that all questionable exercises have not been covered in this brief discussion. However, a point that has been stressed is that certain exercises that are appropriate for some individuals may be totally inappropriate for others. The *quality* of the exerciser's movements is a most critical variable when evaluating exercises for inclusion in a conditioning program; we also suggest that readers consider the following criteria when judging either an exercise or an exerciser:

- Does the exercise have an underlying value that is apt to benefit the target population?
- Does the exercise present an element that could make it inappropriate for some individuals?
- Do the benefits of doing the exercise outweigh the drawbacks?
- Do the exercisers do the exercise in a manner that makes it beneficial?

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The President's Council on Physical Fitness and Sports

The President's Council on Physical Fitness and Sports (PCPFS) was established in 1956 through an Executive Order by President Dwight D. Eisenhower as part of a national campaign to help shape up America's younger generation. Today, the PCPFS serves as an advisory council to the President and Secretary of the Department of Health & Human Services on matters involving physical activity, fitness and sports to enhance and improve the health of Americans of all ages.

The PCPFS enlists the active support and assistance of individual citizens, civic groups, private enterprise, and voluntary organizations to promote and improve the physical activity and fitness of all Americans and to inform the public of the important link which exists between regular activity and good health.

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"When choosing an exercise, be sure that it is appropriate for you—that means doing it will help you achieve a fitness goal and that you can do the exercise in a safe manner. The microtrauma that can occur from repeatedly doing exercises that are unsafe for you can have long term health and injury consequences."

Wendell Liemohn, Ph.D.
Professor, Exercise Science
University of Tennessee, Knoxville

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